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Knowledge Sharing for a Better Tomorrow

Port Everglades Department (PED) Crane and Infrastructure Upgrade, Overview and Lessons Learned

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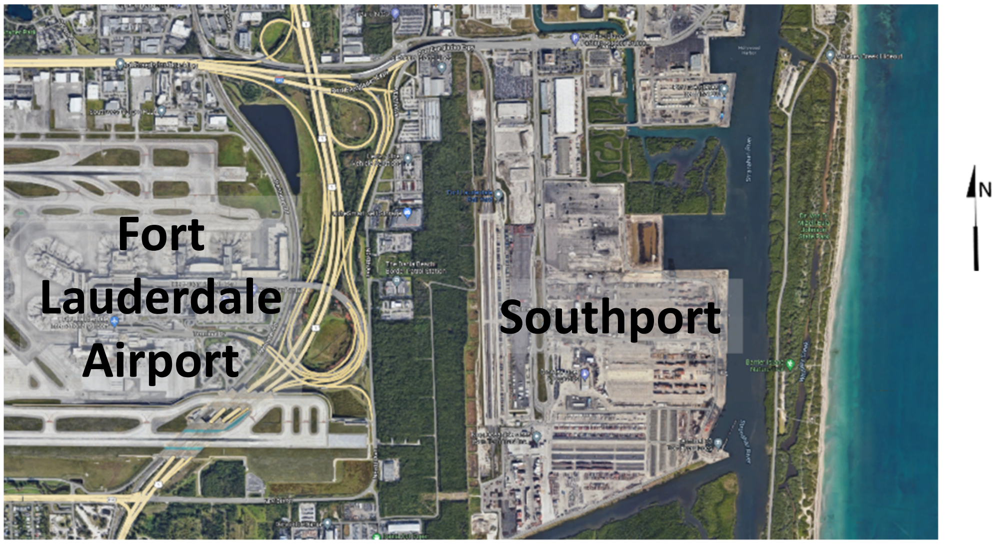
Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design and procurement of dockside container handling cranes and other complex structures. Our experience includes structural design for wharves and wharf structures, heavy lift structures, buildings, container yard structures, and container handling equipment. Our national and international clients include owners, engineers, operators, manufacturers, and riggers. We provide structural, mechanical, and electrical engineering services.

Erik Soderberg is Liftech's president and a structural engineer with over 28 years of experience in the design, review, and modification of a variety of structural systems including hundreds of container cranes, over a dozen bulk loader structures, and over two dozen wharves and piers. Other structures include crane lift and transfer systems and concrete and steel floats.

Port Everglades Southport



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An overview of the project will be provided in these initial slides, then I will present some of the more significant lessons learned.

The project site, Port Everglades Southport, is close to Fort Lauderdale Airport and its flight paths, resulting in significant height restrictions for ship-to-shore (STS) cranes.

Port Everglades 2014 Master Plan

Pre-upgrade | Planned upgrades

Pre-upgrade cranes

New and future cranes

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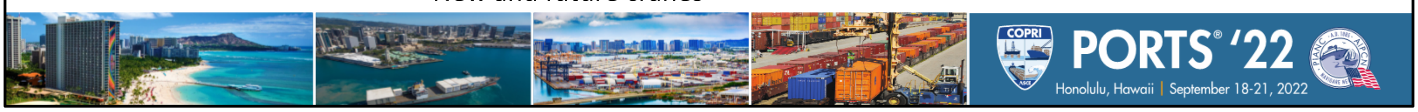
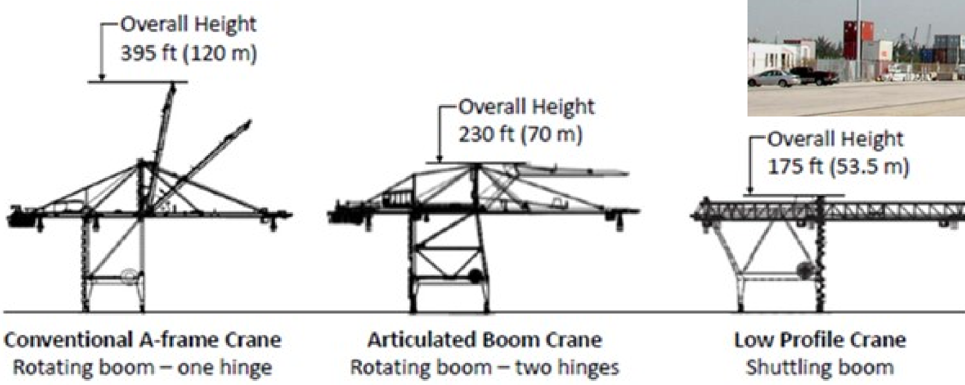


The views in this slide are rotated 90 degrees from the previous slide, north is to the right.

The pre-upgrade condition is shown on the left. The planned upgrades are shown on the right.

The overall project involves adding six new STS cranes capable of servicing larger vessels, extending the turning notch, adding a berth, and relocating existing cranes.

STS Cranes Near Airfields Height Limitations



Lift height:	133 ft (40.5 m) Above Rail
Outreach:	205 ft (62.5 m) Approx. 22-Wide Ship

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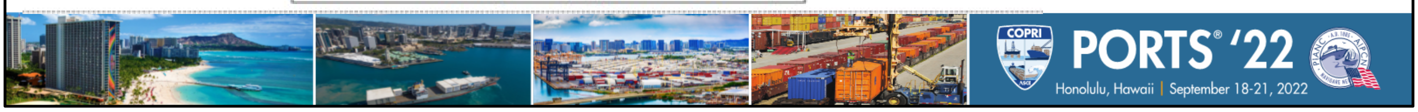
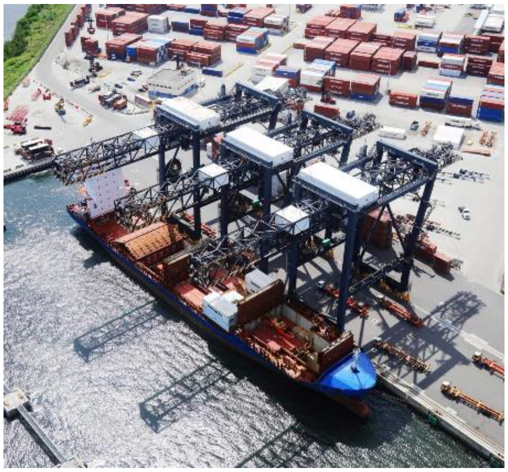


STS cranes near airports have severe height limitations, sometimes requiring use of articulated boom cranes or low profile cranes also known as shuttle boom cranes. The overall height limit for the cranes on this project is 175 ft.

For the same lift height, these are the overall crane heights (how high the crane can lift the container) that would result: conventional A-frame cranes at 395 ft, articulated boom cranes at 230 ft, and low profile cranes at the allowed 175 ft.

Original PED Low Profile Cranes – Shuttle Booms



Booms extended over ship

Booms extended and retracted

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These are the **original** PED low profile cranes with booms extended for operating and retracted in their typical position stowed.

The large boom weight and extreme variation of its center of gravity result in a heavier crane, and significantly larger wheel loads than conventional A-frame cranes.

New Cranes – Berths 31-33 (2020)

Booms extended over ship

Booms retracted over yard

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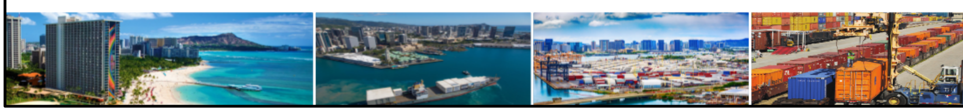

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These are the **new** cranes with booms extended and retracted. Notice the size of the new cranes relative to the original cranes.

Related to this project, PED received an increase in the allowed height clearance envelope.

The new cranes are among the largest shuttle boom cranes in the world.

Crane Parameters

Parameter	Low Profile Cranes	
	90s Samsung	2020 ZPMC
Vessels Served	16 wide	22 wide
Capacity, kip (tonne)	89.5 (40.6)	145.5 (66.0)
Rail Span; ft (m)	100 (30.5)	120 (36.6)
Outreach; ft (m)	145 (44.2)	205 (62.5)
Backreach; ft (m)	45 (13.7)	35 (10.7)
Lift Height; ft (m)	106 (32.3)	133 (40.5)
Overall Height; ft (m)	151 (46.0)	175 (53.3)
Weight; kip (tonne)	3330 (1510)	4600 (2090)
Voltage to Crane, kV	4.16	13.2

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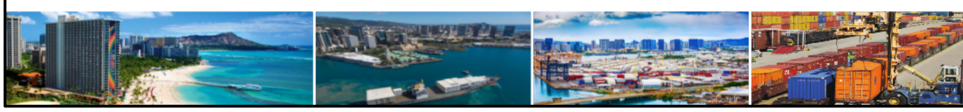

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This slide shows differences between original 1990s Samsung and new 2020 ZPMC cranes.

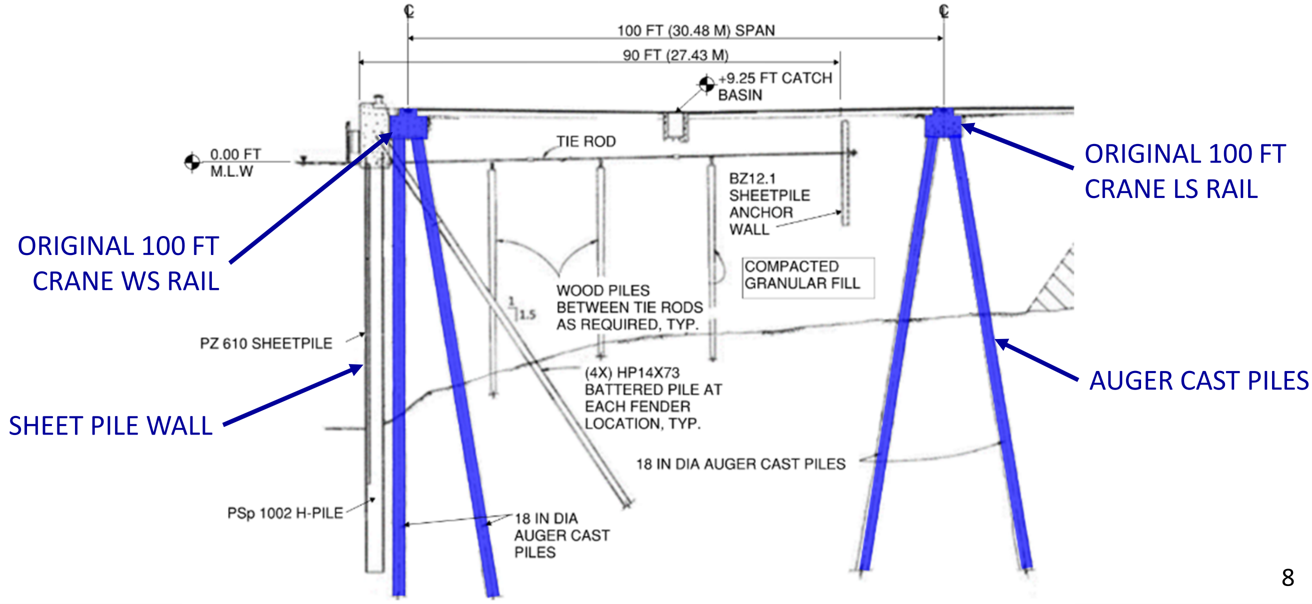
Key differences include ability to serve 22 container-wide vessels instead of 16 wide, and twin-20 30 LT containers instead of single 40 LT containers.

The rail span is increased from 100 ft to 120 ft to limit stability ballast and wheel loads. Offsetting the new rails from the existing rails also allowed continued operations of the original cranes during construction.

The outreach and overall height were able to be increased from the original due to a change by the FAA.

Although the overall height increase from the original cranes is 24 ft (from 151 ft to 175 ft), the lift height was increased by 17 ft, an extra 3 ft, by changing the crane design.

Typical Wharf Section: Pre-Upgrade



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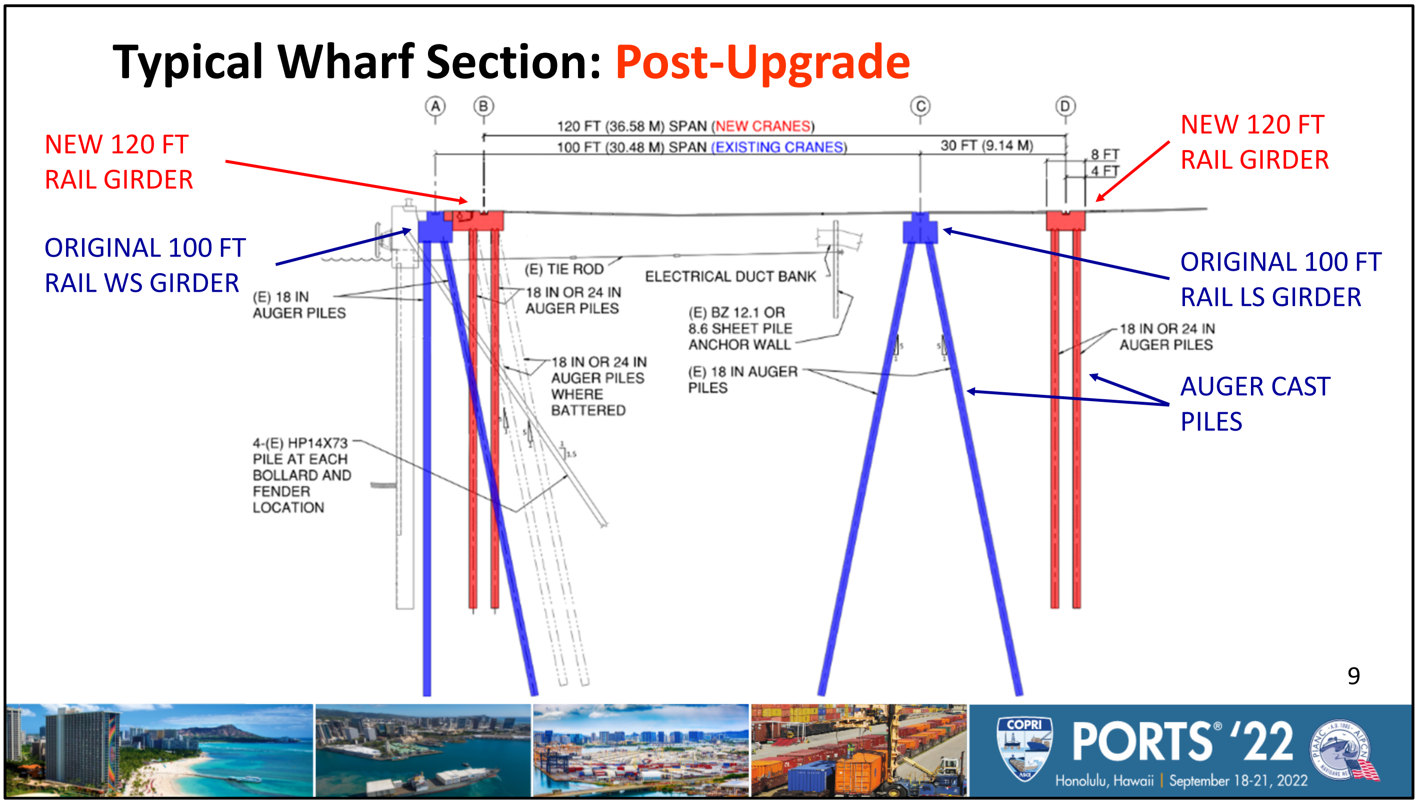
This shows a cross section of the **original** wharf, consisting of a tied-back sheet pile wall with king piles, and reinforced concrete crane girders supported on auger cast piles.

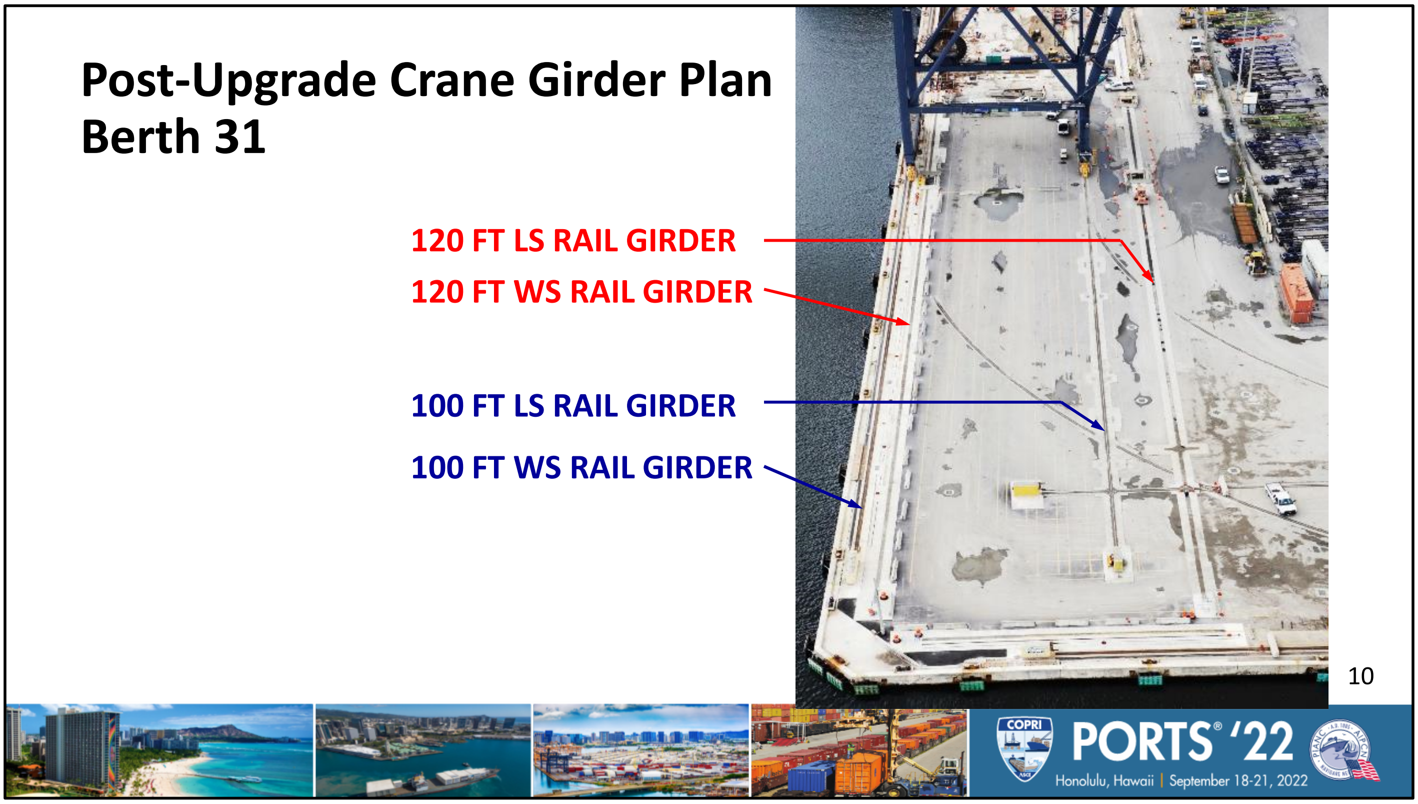


This slide presents the wharf after upgrade.

The **new** structure is in red.

Notice:

1. Girder kept shallow at 4 ft to improve constructability with water level.
2. The many potential interferences for the new waterside girder auger cast piles due to the existing piling and tie rods.



This is an aerial view of the new (120 ft) and original (100 ft) girder systems during construction of the new girder system.

Scope of Infrastructure Work

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Key aspects of the infrastructure work include the new turning basin, 1,500 ft of new 100 ft span rail girder, 2,500 ft of new 120 ft span rail girder, a new switchgear building, and a new power system and service.

Lessons Learned

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Now I will present some of the lessons learned during the project.

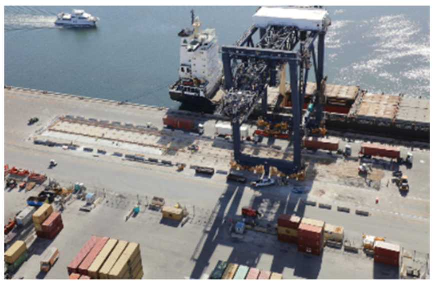
Coordination with Operating Terminal

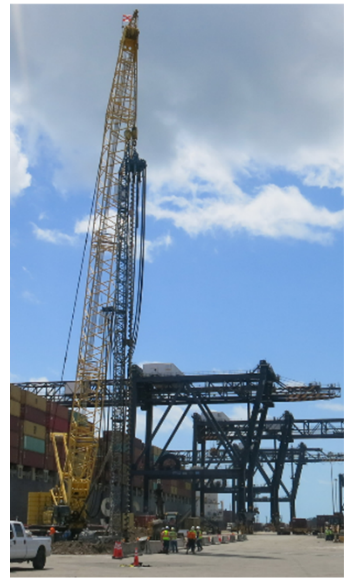
Problems

- Tall pile rig disrupting crane movement
- Stopping girder construction to allow cranes to pass

Solutions

- Weekly coordination meetings between stakeholders
- Routine communication with harbor master





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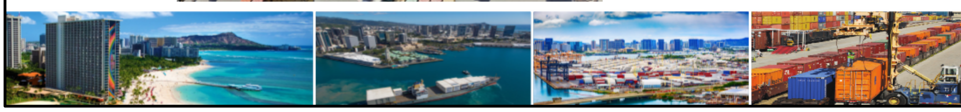

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Coordinating with the terminal was critical to maintaining terminal operations. This took priority over construction.

We found that weekly coordination meetings with the various stakeholders and periodic communication with the harbor master were sufficient to avoid problems and delays for terminal and construction operations.

The auger cast rig is shown in the image on the right.

Coordination was less of a problem than expected.

Auger Pile Construction Tolerances

Problem

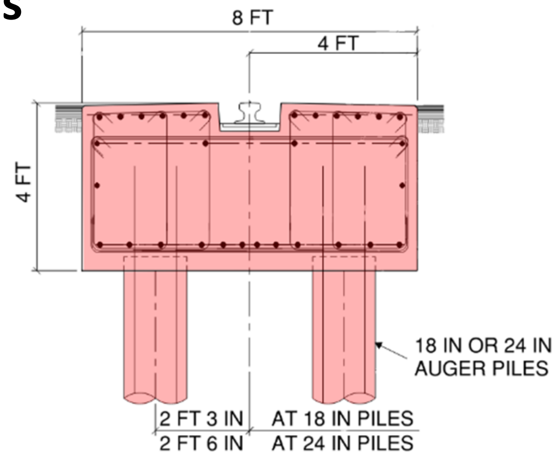
- Design pile location tolerance of 3 in (75 mm)
- Actual offsets up to 12 in (300 mm) to avoid conflicts

Consequences

- Unequal pile loads, reduced pile capacity
- Additional girder transverse and torsional reinforcing

Solution

- Use design that readily facilitates additional torsional and flexural reinforcing
- Pile layout/capacity that can accommodate misaligned piles



TYPICAL BEAM

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Auger pile placement tolerances of 3 inches in plan were considered in the girder design, but due to unexpected obstructions and known interferences being located differently than expected, misalignments larger than these tolerances were common—more common than expected.

The pile misalignments resulted in more torsion and transverse bending than designed for. The design readily accommodated the addition of transverse and torsional reinforcing.

The lesson learned for the next project is to ensure, like the design on this project, that the design can readily accommodate occasional piles that are misaligned and consider larger installation tolerances.

Crane Stowage Hardware Alignment

Tie-downs Stow pins Tie-downs

Tie-downs

Stow pins

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This slide presents the stowage hardware for securing the new cranes for a hurricane. One of the biggest risks to STS cranes in hurricane regions is damage or collapse due to failure of the stowage system. This risk is often underestimated due to not accounting for misalignments, resulting in larger-than-expected stresses in the hardware and anchors.

Crane Stowage Hardware Alignment

Problem

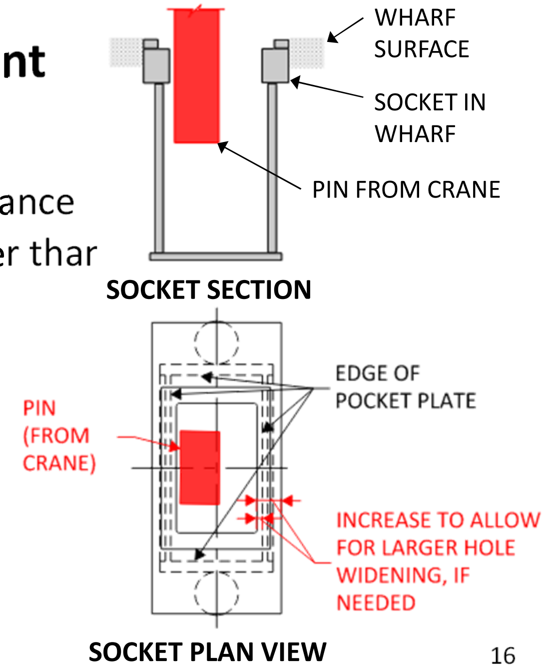
- Some hardware was installed out-of-tolerance
- Crane component misalignment was larger than expected

Consequences

- Misalignments result in larger stresses in hardware and anchors—still acceptable

Lesson

- Design for larger misalignments
- Design sockets for large modifications



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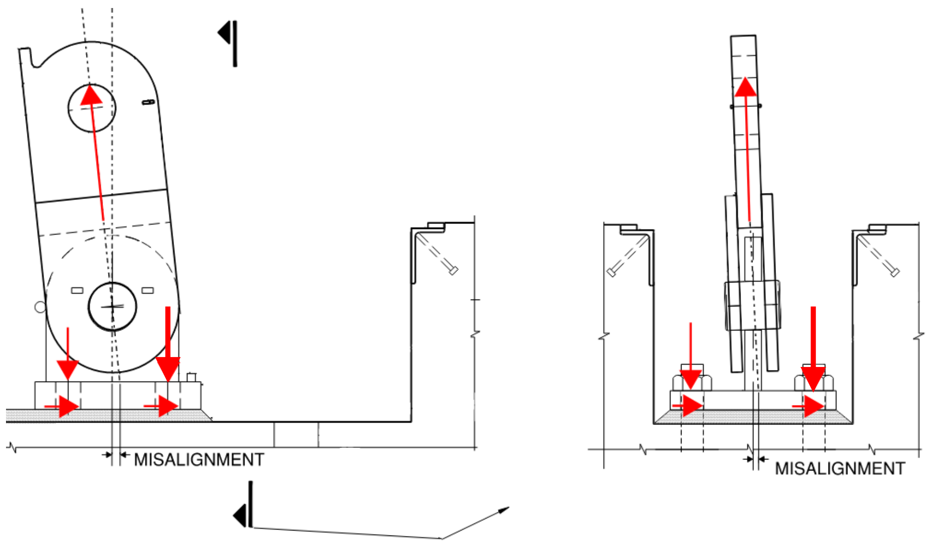
In the crane travel direction, the stowage socket hole is typically made about 3 inches wider than the pin to facilitate pin insertion. Excessive misalignments are not significant to the crane structure, which can accommodate significant racking, but are significant to the tie-down alignment. Misalignments in this direction can be accommodated by trimming the hole, adding shim plates in the hole, or both.

In the direction perpendicular to the rail, misalignments also include the wheel tread width being larger than the rail head, so the pin position will vary depending on the crane position on the rail. Sockets should be designed to accommodate significant misalignment with limited modifications. If tolerances are exceeded, designs will ideally allow easy adjustments to the hole geometry, such as by trimming the opening.

Our lesson learned on this project is to design for larger misalignments transverse to the rail.

Tie-down Linkage Misalignments



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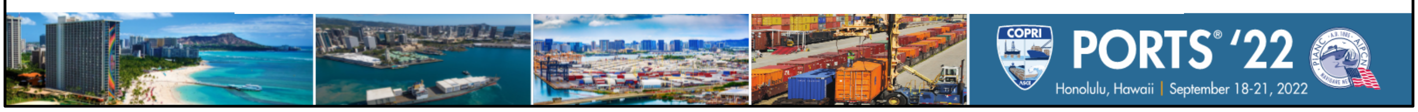


Tie-down rotations out-of-plumb are unavoidable due to the deformation of the crane structure during a hurricane, construction tolerances, and the fit of the stowage pin in its socket.

Misalignments result in local bending in the hardware and uneven anchor forces. Small misalignments in each direction will significantly affect anchor forces. The larger arrows indicate larger forces. For example, if an eccentricity of ½ in develops in each direction, for a 6 in and 8 in bolt spacing, the most heavily loaded anchor will carry a third of the vertical load, 31% more than the average anchor force.

If misalignments are excessive, the additional bending in the hardware and forces in bolts can be a problem.

We had designed for large misalignments, but our lesson learned is to design for even larger misalignments. The additional cost is not significant and reducing the risk to the contractor from significant construction misalignments is also worthwhile. Having increased performance and reliability is a benefit if there are not significant misalignments.

High Strength Materials: FY=100 KSI

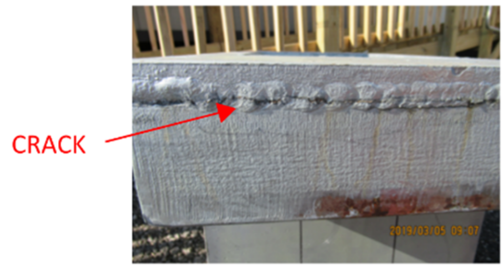
Issue

- High strength materials were used to facilitate tie-down hardware handling
- Difficulties fabricating and galvanizing high strength materials

Lesson Learned

- Have strict/clear requirements for fabricator and galvanizer – experience, responsibility, procedures
- Consider using lower strength material, e.g., ASTM A709 HPS 70W

SECTION THROUGH TIE-DOWN PIN



SECTION THROUGH STOWAGE SOCKET

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We have used high strength materials on many projects including wharf and crane projects.

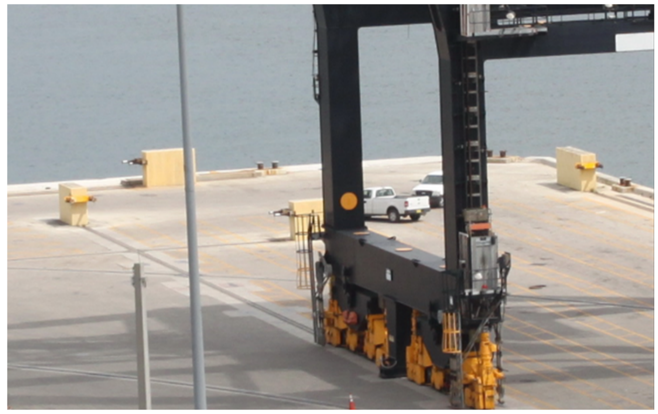
Reducing weight is always the benefit. On wharf projects, the improvements to handling and securing hardware is a significant benefit.

Fabricating materials with 100 ksi yield strengths has significantly greater risks. For example, with hot dip galvanizing if typical practices are used and materials are cooled quickly, thermal stresses equal to the yield strength can develop in the fabrication. The fracture critical crack size is proportional to stress squared, and higher strength materials have lower toughness, so the fracture critical defect sizes become very small, fractions of an inch. Small defects in the base material or weld can fracture just from cooling.

Our lessons learned are to ensure that the contractors are knowledgeable about the added difficulties, responsibilities are clear, and proper procedures are in place.

Another lesson is to consider a lower strength material such as ASTM A709 HPS 70W that will be 30% heavier, but still 40% lighter than 50 ksi material, and less prone to fabrication difficulties.

Original Non-Compact Crane Stops – Original Cranes



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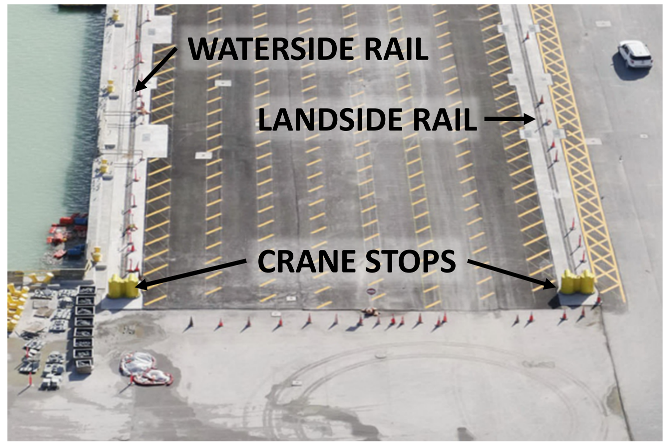
Crane stops for the original cranes were large and consumed significant space on the wharf, limiting the extent of crane travel and resulting in accidents with yard equipment.

New Compact Crane Stops – Original Cranes

Design Load = 800 kip+10% lateral/rail factored



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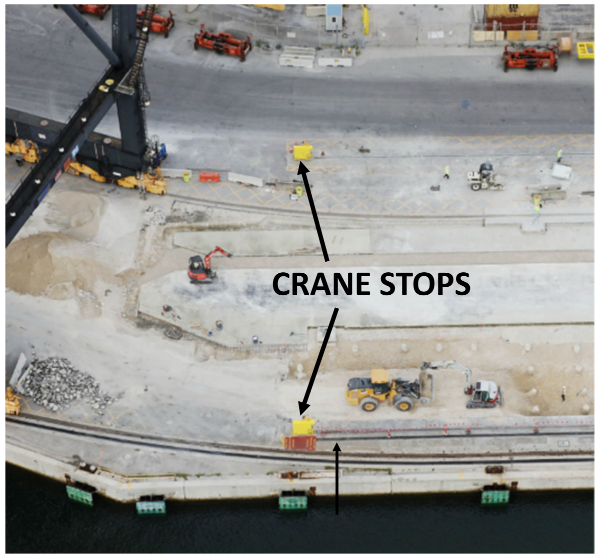
For new stops, we determined it was practical and worthwhile to design for "compact" stops to reduce space, reducing the risk of interference with yard equipment and increasing the length of usable rail girder.

A rounded geometry was used to reduce risk of damage to yard equipment in case of collision.

The new stops for the original cranes are shown on this slide.

Compact Crane Stops – New Cranes

Design Load = 1,250 kip+10% lateral/rail factored



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A similar design approach was used for the new crane stops for the new cranes. This stop design is significantly stronger, able to resist a 1,250 kip (680 tonne) factored lateral load at the bumper level.

Similar to the stops for the original cranes shown on the previous slide, the lesson learned is that compact crane stops are practical.

Pavement Performance

Issue

- Little time for pavement set due to operating terminal

Lesson Learned

- Specify pavement for early strength

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In some instances, container handling equipment was operated on new pavement 24 hours after placement, requiring repairs.

The lesson learned from this is to specify a pavement with adequate early strength to reduce the risk of damage if there is a significant risk of earlier-than-expected loading.

New Utility Service

Issue

- Significant time allotted to obtain new power service; despite this, more effort and time were required than expected

Lesson Learned

- Allow for extra time/effort working with utilities
- Early on, document expectations and needs with utility
- Ensure owner budgets can support potential additional costs

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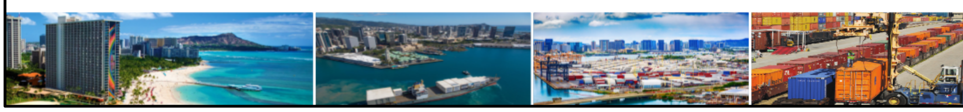

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Despite planning for significant effort and time to coordinate with the utility company, we found that it was even more effort and time than expected.

The lesson learned is to allow for extra extra time and effort, but also document expectations and needs early on with the utility and ensure the owner's budgets can support potential additional costs.

Acknowledgements

For guidance and teamwork throughout the project

- PED Infrastructure and Crane Departments
- Liftech Team including subconsultants
- Moss Kiewit Joint Venture (MKJV) – General contractor and their subcontractors
- Atkins Global – Construction Manager, Kevin Callahan

Aerial photographs - MKJV

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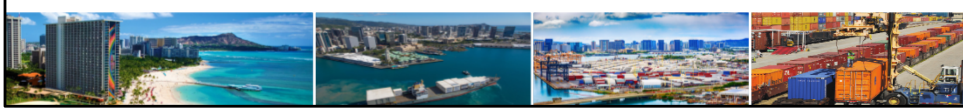

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We had some help throughout, so thank you to those acknowledged above.

Thanks for attending my presentation and let me know if you have any questions.

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